High Speed Rail in India- the stepping stone to supersonic mobility

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With achievement of financial close, commencement of detailed planning and land acquisition activities for the Mumbai – Ahmadabad HSR project, India is well on way for a quantum leap in speed, riding comfort and technology advancement in rail based inter-city travel. The next step has to be planning for a HSR network. India needs ultra-fast, intercity trains now. There are several dense sectors in intercity passenger movement in India: Mumbai-Delhi, Mumbai-Bengaluru, Chennai-Bengaluru etc. The advantage of high passenger demand, sheer growth in urban population and economic activity has fueled a rapid expansion of civil aviation in many of these sectors. HSR is an ideal travel mode for mass transit on these routes, far more fuel efficient and low on carbon emission, than air travel, with the added advantage of being able to string several densely populated, high growth towns/cities, en-route. This adds to commercial viability.

Take Mumbai-Ahmadabad as an example.

-The legacy conventional rail route would focus on travelling via Mathura, Kota, Vadodara, onward to Surat and Mumbai. HSR demands more passengers and more insight in route planning.

-Taking the route from NCR-Delhi (covering Ghaziabad, Noida, Gurgaon) to Mumbai, via Jaipur, Ajmer, Chittorgarh, Udaipur, Dholera, Surat, Nasik, Thane and Belapur, immediately increases the potential passenger demand, as, this route would link religious/ tourist centers, and new economic growth hubs in the DMIC region. Several other such alignments are needed for new economic corridors like Bengaluru-Mumbai (BMEC) and Bengaluru- Chennai (BCIC).

After China, India has the highest number (53) of big cities in the World. HSR connectivities to these big cities will act as a catalyst to enable them to become more powerful engines of growth. Just take a look at Delhi - Mumbai HSR Corridor. A single HSR train can string as many as 14 or more big cities in a journey from CBDs of NCR to CBDs Mumbai (Belapur included) within a running time five and a half hours. No Air line can achieve such a feat. Such a Corridor is exactly comparable with Beijing - Shanghai HSR. In a hugely populous country like India, this is the finest and most economical way to provide inter-city ultra-fast and ultra-low carbon connectivity. This sample demonstrates India has sufficient vast intercity distances, to demand designing of a new time sensitive travel mode.

Indian Railways successfully brought down costs of conventional railways in India, through indigenization and localization, under various upgrades of rolling stock. However, the investment cost of HSR is considerably higher than conventional railways, as, higher speeds dictate more exacting precision in safety and technical standards. India does not have HSR technology residency. In my previous writings on HSR in India[1], I have stressed that for HSR to become an affordable public transport network, India will need a planned approach and strategic roadmap for technology acquisition. With induction of HSR in India, there is an imperative need to focus on indigenization of the core technology platforms of HSR, standardize rolling stock

[1]Economic and Political Weekly, Volume XLIX No. 28 of July 12, 2014 and
Strategies for Making Railways a Sustainable Transport in India, Chapter 4, "Transportation Sector in India and EU, Problems, Prospects and Opportunities for Development, Edited by Rumi Aijaz, Academic Foundation, New Delhi.

and engineering designs, indigenize manufacturing to steadily reduce investment and maintenance, repair and operating costs. Taking a quantum jump in the existing knowledge base of the Indian rail ecosystem to Advanced Rail Technology will dictate a paradigm shift in the country's approach towards transfer of technology. This author is working on publishing research on a new funding and delivery model for HSR in India to make HSR more affordable. In this article, a few observations on HSR and competing transport technologies and technology transfer are presented.

HSR versus Maglev versus Hyperloop

When the first international seminar on HSR for India was held in 2007, under the aegis of MOR and AITD[2], views had been expressed by members in the seminar, that India should consider leapfrogging to a new level of technology rather than bind itself to HSR. This was the period when China already had a commercial Maglev Line between Shanghai and Pudong Airport, capable of reaching 431 kmph[3], (whereas HSR was mostly being built for 25-350 kmph).

Today there is a sense of déjà vu. As India ushers in HSR, through the Mumbai Ahmedabad project, several transport planners and authorities in India are giving an excited and positive response to a higher speed transit system- the Hyperloop. Introduced by Elon Musk as a revolutionary inter city transit technology[4], the Hyperloop challenge is all about reducing air resistance and friction in travel modes to achieve extraordinary speeds, with innovations towards cutting investment and operating costs. Once again, there is resurgence for exploring faster passenger transit modes, before committing to HSR. The Hyperloop technology, with its stated promise of lower cost, high energy efficiency and speed to beat even airplanes, has caught the imagination of many transport planners world over. India too is no exception. Virgin Hyperloop One has promised to build Hyperloop connectivity between Pune and Mumbai. HTT have signed an MoU with Andhra Pradesh to build Hyperloop between Vijaywada and Amravati. The tag line "*lower cost and higher speed*" poses a challenge to planning the future technology upgrade of surface transportation. Should India wait before expanding HSR? Should India plunge in to Hyperloop? A few reflections on this arise.

a. There are recent developments which brings good news. Like the first full size Hyperloop capsule named "Quintero One " is now on display in Spain by Hyperloop Transportation Technologies (HTT) . Dual layer composite material called "Vibranium" has been used. However, trial runs are yet to take place. Hyperloop's technology, operational safety and commercial viability are all still at development stage.
b. Transition from Technology Ideation to viable commercial operation has a legacy of long time lines for all new transport systems in nations with technology residency. (Refer Box 1 and Diagram).

[2] The Asian Journal, Vol. 14, September 2007, Number 1, High Speed Rail

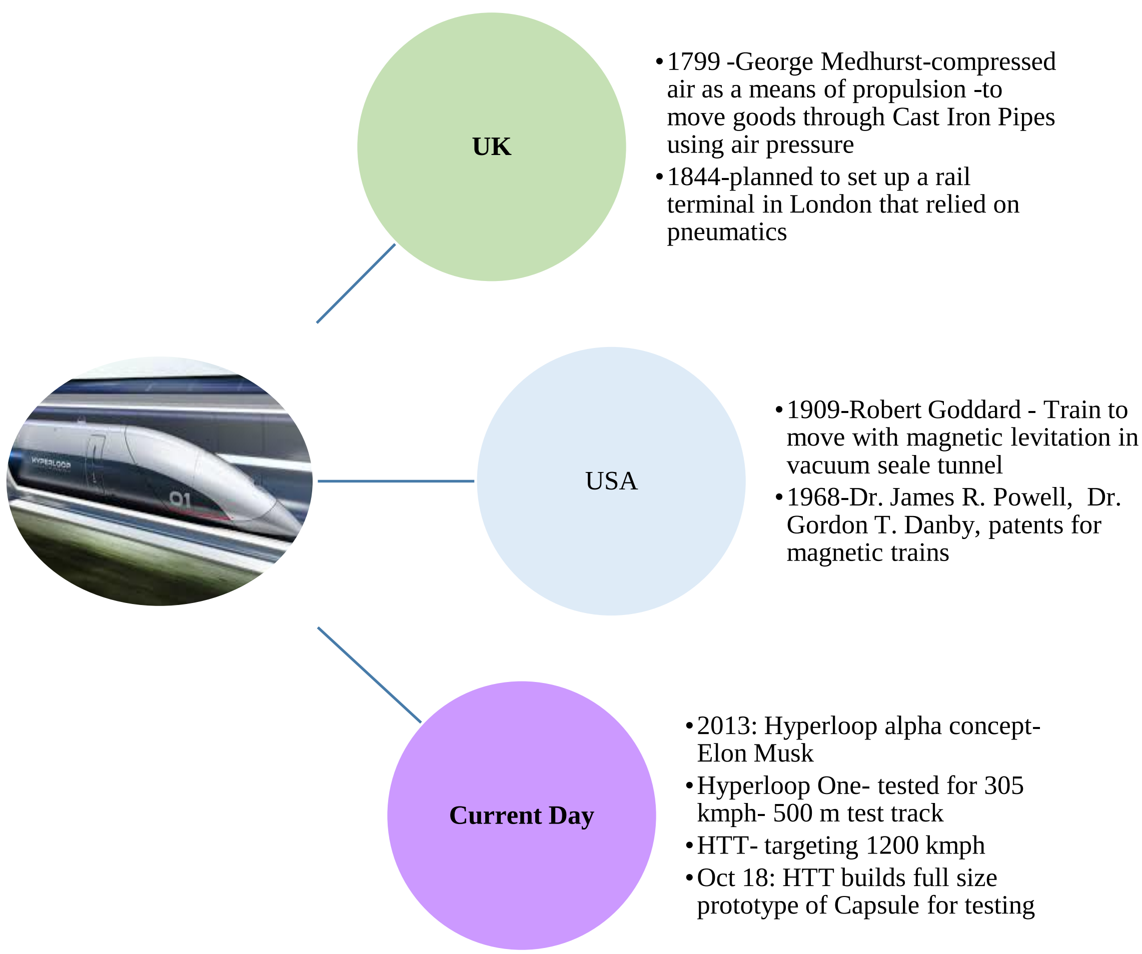
[3] https://en.wikipedia.org/wiki/Shanghai_maglev_train

[4] hyperloop_alpha-20130812.pdf

Box 1: Time Line of magnetic levitation trains- a few milestones

- 1968-69: Powell Gordan Dandy first design of Maglev train
- 1991 German Government certified operation of train for public transport
- 1997 Federal Parliament passes Transrapid Requirement Law
- 2003 Japan achieved a test run speed of 581 kmph, one year before Shanghai Maglev opened
- 2004 Shanghai Maglev line commenced commercial operation as an airport -Central Business District (CBD) passenger Connectivity line (30.5 km) with a top speed of 461 KMPH
- 2013 Japan commits to build the first 286 km medium distance intercity Maglev line between Tokyo and Nagoya. *Expected to open for commercial operation by 2027-2030*.
- 2015 Japan achieved a top speed of 603 KMPH with a 7 -Car Maglev train on a 43 km test track L-Zero, Yamanashi. (Shanghai Maglev route where commercial operation is on for more than 14 years is smaller than the Yamanashi test track route length).

Diagram 1: The ideation and testing timeline of Vacuum Tube Trains/ Hyperloop



In contrast to maglev and Hyper loop, HSR is a technologically proven and safe, commercially viable transport mode. The civil aviation and road transport sector in India are already facing capacity bottlenecks. Delaying a HSR network, in a sub continental size country like India, may be detrimental to transport logistics. Sustaining a public transport network on promise of Hyperloop, without technology residency, would be even more difficult, particularly when, it is a technology that is still under development.

c. Experts have expressed concerns about cost and technology for mitigating air pressure impact in the near vacuum like low pressure tubes. Damage to the human system due to possible leakages or failures are still being debated. Thus safety of Hyperloop is still to be proven.

d. Speeds demonstrated so far have not yet crossed HSR and Maglev speeds and might involve much more developmental work. As for commercial viability advantage the jury is still out.

e. The stated cost advantage of Hyperloop over HSR is far from evident. Investment Costs per km, quoted range from 17[5] million USD to 40 million USD[6]. The carrying capacity of Hyperloop appears to be less than HSR. A US feasibility study[7] states that Hyperloop could carry 840-3360 passengers per hour against 12000 per hr in HSR). Hyperloop costs would increase if more tubes are added to accommodate more passengers.

f. All this does not make Hyperloop cheaper than either HSR or for that matter even Maglev. The World Bank has rated HSR of China as perhaps the most economical in the world[8]- built though aggressive localization and standardization of designs and manufacturing. India has not yet been able to obtain HSR technology for indigenisation and localisation. With well proven credentials of developing Space and Satellite technology involving PSLV and GSLV Systems, India can well emerge as a dark horse in HSR or Maglev or even Hyperloop technology systems and product development. India can rival China in driving down HSR costs for it's domestic HSR network. India will not violate technology transfer conditions to emerge as a rival to the technology provider. However, India can be a Joint Venture or Alliance partner with the technology providing country. This can be a mutually beneficial arrangement. A lower cost achieved through indigenization of HSR, immediately increases the market potential, given the vast size of the country and more than 53- one million population plus- cities.

g. India needs ultra -fast Intercity trains now. The apprehensions on cost of HSR need to be confronted through public debate. These projects are not necessarily more expensive than

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[5] https://www.theguardian.com/sustainable-business/2017/aug/04/hyperloop-planet-environment-elon-musk-sustainable-transport

[6] https://cleantechnica.com/2016/12/17/hyperloop-40-million-per-kilometer-hyperloop-transportation-technologies-chairman-claims/

[7] https://trid.trb.org/View/1417887Hyperloop Commercial Feasibility Analysis, High Level Overview, July 2016

[8] http://documents.worldbank.org/curated/en/695111468024545450/pdf/892000BRI0Box3000china0transport09.pdf

an international quality Expressway Project in India. The costs of the recently completed 9 km section of the 14 Lane Expressway, between Delhi Meerut, are about US $ 14 million per km. The completed cost of 6-lane Noida -Agra Expressway[9] too, were reported as US $ 14 million per Km. Chinese HSR per Km costs are US $ 17-21 million per km. Thus delaying expansion of HSR, only on the premise of high cost, is not well informed decision making.

Strategies on Technology

Public sector supported R&D and innovation has thrived in countries with advanced rail technology. Way back in 1990's, when Japan and Germany had demonstrated maglev, USA administration too dallied with funding research on making maglev a reality in USA[10]. In 1992, Senator Moynihan, argued on the need to catch up on the technology to avoid a situation where USA ends up buying it, despite having patents and original research on shore. Once again, these countries, that are active in research in advanced rail technology, with public sector supported R&D, have come forward to keep a foothold on developments taking place in the Hyperloop technology. China for one, has taken a strategic stand. Chinese statePSUs are investing one billion USD in Arrivo and 300 million USD in HTT[11]. If we see the history of HSR in China, the confidence of China rests on its R&D and innovation success. From a new comer in 2006, China has raced ahead to establish the largest HSR network of 20,000 km plus (and growing), in the world, with complete indigenization, on the strength of its R&D institutions, research centres and public funding. China has strategically offered its country for hyper loop testing with the added promise of running trains on the One Belt One Road routes- an enticing transcontinental network. This initiative has in fact attracted many counties including Japan. The China Aerospace Science and Industry Corporation (CASIC), has already announced plans to take Hyperloop speeds to 4000 kmph and export these trains to countries investing in the OBOR[12]. This is how china leverages its investments. A controlling stake in Hyperloop startups will pave the way for eventual indigenization of the technology in China, to lower costs.

When India is on the brink of framing strategies on absorbing HSR technology, the social actors, like Government departments and policy makers, need to be conscious on the messages that manufacturers of Rail products will absorb. Mixed signals on the likely future transport choices could well act as a hurdle in active participation of domestic industry and R&D institutions in indigenization of HSR technology. Indigenization of conventional Railways was achieved through active participation of domestic manufacturers in the private and public sector and conscious policies of the Government. Similar indigenization is not yet seen in Metro signaling and rolling stock. Susana Martins Moretto's case study[13] suggests that manufacturers in the HSR

[9] https://economictimes.indiatimes.com/news/economy/infrastructure/yamuna-expressway-interesting-facts-pictures/articleshow/15421577.cms

[10] https://www.nytimes.com/1992/03/03/science/new-funds-fuel-magnet-power-for-trains.html

[11] https://futurism.com/the-byte/china-hyperloop-crowded-highways

[12] https://qz.com/1066455/china-aims-to-build-a-supersonic-flying-train-that-would-put-elon-musks-hyperloop-to-shame/

[13] Societal Embedding in High Speed Train Technology Development: dominant perspective from a case study, Enterprise and Work Innovation Studies, 7, IET, pp 57-73

supply chain have deployed Constructive Technology Assessment **(**CTA)[14] as a strategic intelligence tool, reflecting societal embedding in HSR technology development. The process was given a push by various EU legislations on HSR, which has forced the manufacturers to use techniques like constructive technology assessment to improve their competitiveness and performance, to match customer expectation. This helps to mitigate market failure and in fructuous investment. Perhaps the policy signals are not in line with generating a market confidence towards investment in HSR in India.

The takeaway here is that India needs to wake up to the need to review its transfer of technology and technology absorption strategies, if it wants to catch up with China and other new entrants in their very high speed surface transport infrastructure like HSR, Maglev and possible future Vacuum Tube Trains.

This is not an easy task. A well planned strategy is needed as early as possible. After satisfactorily embarking on the Mumbai-Ahmedabad HSR project, for taking up the remaining legs of the Diamond Corridor[15], India must think and act like a strategic buyer of HSR (or Maglev or other Intercity High Speed Surface Transportation Technologies) using India's own funds. If Hyperloop loop proves itself to be a success and emerges as a challenger to HSR or intercity Maglev, an approach of 'benign technology transfer' policy may be pursued. By benign technology transfer, I mean, joint development and avoiding partners competing against each other in the international market, without reaching a mutual understanding. For emerging as an Advanced High Speed Surface Transportation Technology developer nation, India needs to prepare a strategy of its own. The following is a suggested road map for developing such a strategy.

Roadmap on HSR technology

1) *Build an ecosystem for absorbing ART*: The country has to build the capacity to absorb foreign knowledge. A wide spread eco system of Engineers, Faculty and Students, Interns, Scientists, Researchers and Technicians has to be created across India's vast network of IITs and NITs to absorb the tech knowhow. Designs and drawings and technologies have to be shared across this ecosystem to foster organizational level learning. Knowledge of the atomized technology platforms will require a large team of Indian scientists to specialize in understanding system integration and body shell designs and material components bogie traction converter, traction control, network control and track systems.

[14] Constructive Technology Assessment involves the engagement of social actors (consumers, citizens, corporations, social groups etc.) in influencing design and technical change. The CTA add a dimension beyond technology management through promotion and regulation. It helps technology become more sensitive to likely responses to technology impact and broadens the process of technology development. https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/constructive-technology-assessment, https://www.britannica.com/topic/embeddedness

[15] Railway Budget Speech 8, July 2014

2) *Nurturing an appetite for R&D*: India has a vast reserve of engineers and researchers who are alumni of the 16 IITs, 31 NITs and institutions like Indian Institute of Science, Bengaluru, all national level elite tech Universities. The recruitment processes and standards of IITs, IISc, and NITs are as rigorous as any of the World's most formidable entrance examinations to crack like Gaokao national entrance examination of China, CSAT Entrance Exam of South Korea, Concours of Grande Écoles of France or the selection process of Russell's Group of Universities in UK or the Ivy League and their rival prestigious Universities like MIT, Stanford of USA. With such a rich harvest of the finest and internationally recognized talents in India, both as faculty members and students in these academically elite institutions, India is well poised to fully absorb and digest HSR technology provided HSR India is able to attract and create a talent corral. They can not only absorb the advanced rail technologies, but also innovative competitively with China or any other country in bringing down costs for the domestic market. What is lacking is the R & D appetite and competitive spirit of India's State and Private Enterprises and also MSMEs, in high - tech components manufacturing. Even though Metro Rail could encourage many high quality construction firms, the limited number of these firms is insufficient to meet our country's total requirements. Most of these companies are reluctant to acquire international skills through even acquisitions and mergers with international companies, that have rich experience in advanced rail infrastructure. This is the route presently being adopted by Chinese State and Corporate Enterprises. Another problem is that even the few State and Corporate Enterprises that are capable and competitive, including those under Railways and Department of Heavy Industries, cannot offer opportunities by way of attractive project -oriented Internships to talented students from nationally important institutions like IITs, NITs etc. The success of other nations in encouraging innovations is partly through a close integration between industry and academia. The industry can be careful in selection of talented students and engineers for attractively paid-Internships which are linked to high performance output and innovation related to Advanced and new cutting edge technologies. Like any of these Japanese, German, Korean, French , US and other R & D promoter MNC Companies, India too should offer attractive internships with USD 12-16 per hour wages with free but no-frills accommodation and where required , to-and -fro Train fares or Air Fares. These internships must be linked to project -oriented nationally beneficial outcomes.

3) *Tech procurement Contracts*: For Contracts where Tech transfer is involved, procurement procedures must be drafted by highly qualified expert groups and adopted by Government as national policies, to prevent controversies to achieve tech transfer absorption with desired cost efficient outcomes. At present, even the most complex defence contracts are governed by the same autoschediastic purchase procedures as applicable for buying office stationery. Existing Contracts cannot be governing nationally important technology transfer, absorption and developing patentable quality innovations and products development. When it comes to Technology Transfer - embedded Procurement Contracts, the drawings, designs, metallurgy and construction technology and system integration platform knowhow may need to be handed over to the user country agencies. At this stage itself these new technology platforms have to be shared with a larger base of talent pool to enable sustaining the absorption of the new technology. R&D has to be an ongoing exercise. Localization is not a one-time affair. Transportation of passengers is a high - safety operation. Indepth knowledge of all predictable

and unforeseen issues will be required and the HSR implementing authorities need to share all designs drawings and knowledge with Industry and academia for a continuous support system. This has to be well documented in contracts to avoid controversy and align with accepted national interest in a transparent manner.

4) *Strategic Negotiations*: HSR and Maglev can be expensive. While negotiating transfer of technology and seeking to expand the in house knowledge base, India has to project its capability of cheaper manufacturing costs and demonstrate the benefits of a large domestic market. The terms and conditions of engagement while procuring HSR should be for joint design and product manufacturing with commitment to develop local brands. The custodians of the original technology are constantly improving their products. Once having inducted HSR, continued dependence, on import of material and know, how has to be curtailed. It should not take too long for India to come up with innovations required to transform the advanced technologies in to perfect harmony with Indian conditions. This in turn can result in increased use of locally available high quality resources to lower the cost of advanced technology transportation infrastructure like HSR, Maglev or Vacuum Tube Trains. Such developments will make it possible to scale up and spread the HSR network throughout India, opening up a huge market.

5) Institutional Backbone: Strategic negotiations, Absorbing Technology, Disseminating knowledge in academic institutions to foster future growth and more well informed decision making, all will require a revisit of institutions involved in HSR. A frame work is suggested below:

A. A *National High Speed Rail Commission of India* (NHSRCI) which will:

(i) Draft a National High Speed Rail Policy for approval of Parliament. Necessary for public acceptability, avoiding disputes on alignment, economically rational decision making etc, without burdening public exchequer.

(ii) Oversee acquisition of complete transfer of HSR technology- from drawings, design and metallurgy to manufacturing, preventive maintenance and routine maintenance practices.

(iii) Developing Safety, Operational and Tech Standards for HSR in India- track, rolling stock, vehicle control systems, signaling, passenger comfort, noise and vibration level etc.

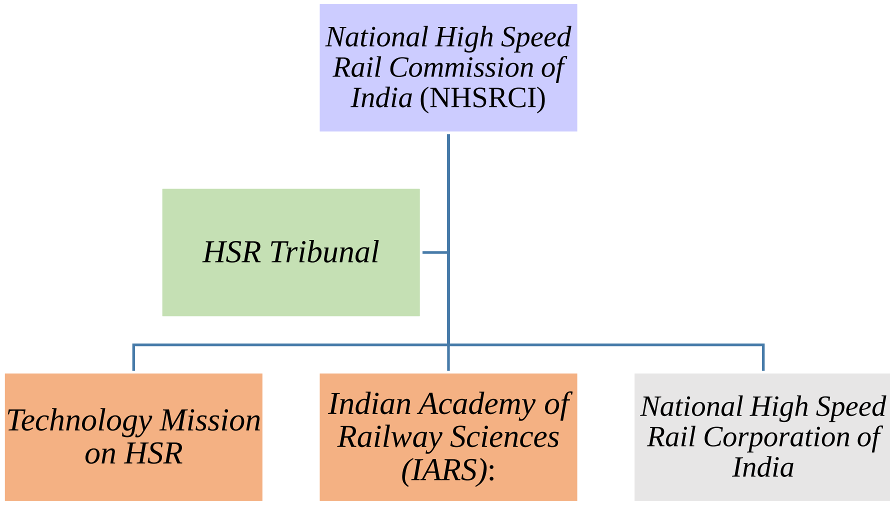
(iv) Decide on Vendor Development policies

(v) Function as the National Regulator for HSR and evolving future Technologies like Maglev and Vacuum Tube Trains or Pods

(vi) Draft special procurement contracts for Transfer of Technology, settle terms of engagement with domestic manufacturing entities, with Non Disclosure conditions for private vendors selected.

(vii) Select Mentors for R&D and sharing tech knowhow across academia

This body will be multi Ministry and Multi Disciplinary with support of national and international experts.



B. A *Technology Mission on HSR*- a multi-Ministerial body involving Ministry of Urban Development, Ministry of Railways, Ministry of Finance, Ministry of Commerce (DIPP), Department of Science and Technology, Department of Space, DRDO etc under the aegis of perhaps NITI. The Mission is to be tasked to set up Technology Development platforms in collaboration with R&D centres in Indian Institute of Science, IITs, NITs and leading Engineering colleges and Manufacturing sector industries of India, who are willing to commit to complete localization of the Technology of HSR in India. This cannot be left to market forces alone. Intensive mentoring and project specific internship in HSR industries, of IIT and NIT students, under direct supervision of Scientists, Researchers and Professors of science and technology is required in a mission mode. The target has to be in depth study and assimilation of technology platform of every aspect of the ART- the body design, the track resilience features, chemical processes of rail and steel structures, curing processes, traction and braking systems, system integration of all parts of the vehicle guidance and control systems and so on.

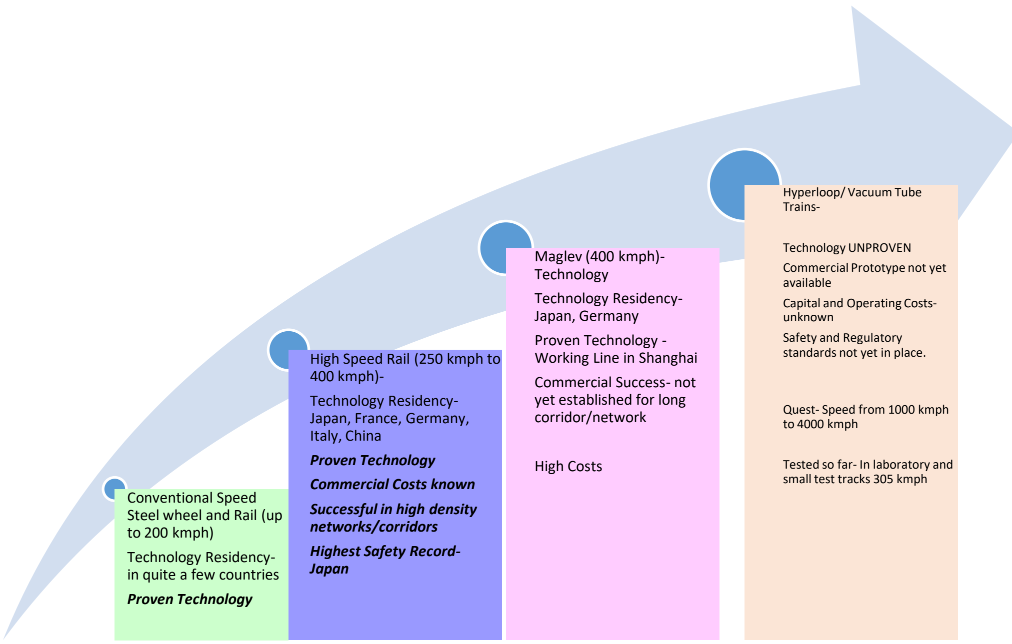
C. *National High Speed Rail Corporation of India*- NHSRC will be in charge of Project Implementation and will function under the policy guidance and oversight of National HSR Commission. The NHSRC can outsource the Programme Management to internationally reputed program management companies who have been associated with project and program management of HSR and Maglev projects in countries where HSR projects were implemented.

D. A *HSR Tribunal* to resolve disputes in regard to procurement actions and conducting forensic audit of procurement activities and matters relating to Technology Transfer and all Patent related matters, on a fast track mode.

E. *Indian Academy of Railway Sciences (IARS)*: Set up and nurture dedicated R&D centres, testing facilities and HSR innovation. Will manage test bed and Test track as a multi use facility, which could also earn revenues from testing metro coaches and other standard gauge rolling stock for even international companies. Will work in close collaboration with *Technology Mission on HSR and* report to *National High Speed Rail Commission of India.*

Conclusion

India needs to decide on which technology should serve as the back bone for the next country



wide rail network upgrade.

India needs to decide on which proven technology should serve as the back bone for the next country wide Diamond Rail Corridor. Businesses like Intercity transport can flourish only in highly populous countries which have a large number of big cities. That is why it became a commercial success in China. Further China was also able to bring down the cost of HSR projects. The project costs plummeted after technology transfer and it's indigenization and localization.

One reason for resistance to share technologies in expensive public transport modes like HSR, Maglev etc is the apprehension that the technology recipient nation would take advantage of its capacity to indigenize and localise the technology transferred, and wield that advantage meant only for domestic HSR development, to compete with the technology provider nations in the overseas markets. This can be prevented by drafting contracts with such explicit conditions. Such mutually satisfactory arrangements were made between Suzuki Japan and India's Maruti Udyog in the past which prevented competition between Joint venture partners in overseas markets. India's approach to technology transfers has always been ethical and has never been embroiled in any such controversies. This is particularly so in all rolling stock procurements made by railways. Therefore, in the case of High Speed Rail technology transfer too, India can adopt Maruti Udyog -Suzuki model of indigenization and localisation strategy, with a view to bringing down project investment costs and operational costs, for domestic transport network sustainability.